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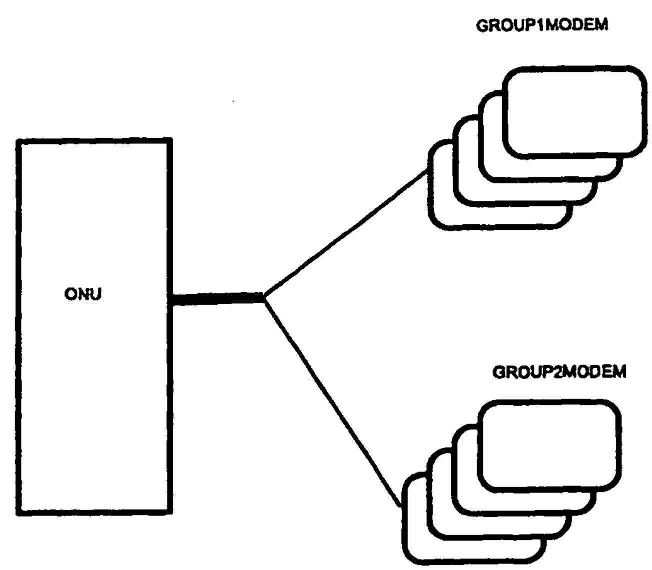

(57) Abstract

The present invention combines the advantages of OFDD with Frequency Divided Duplex (FDD), thus enabling the reach of a vdsl transmission system to be extended. The present invention requires that: the use of an extra cyclic prefix; and for longer lines, the frequencies above the FDD band are not used, in other words. This in turn means that: time-synchronisation is performed between all transmitters in the ONUs and the NTs; timing advance is calculated from the line length; and different sub-carriers are used in up-stream and down-stream directions.

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Improvements in, or Relating to, Digital Transmission

The present invention relates to digital transmission systems employing VDSL and/or ADSL with reduced NEXT, and methods of transmitting data with reduced NEXT using VDSL and/or ADSL.

Current proposals for the use of VDSL (Very high rate Digital Subscriber Line) suggest that it should be limited to a maximum range of 1.5 Km. Most telecommunications operators have access networks where a 1.5 km transmission range would mean that many subscribers are excluded from receiving service. If VDSL is to be offered on a universal, or near universal basis, subscriber lines need to be shortened. This would be a prohibitively expensive operation demanding the wholesale reconstruction of telecommunications networks. Instead of shortening subscriber lines it may be desirable to offer subscribers the transmission capacity that is available on the lines they currently possess. This kind of graceful degradation in capacity means that the reach of VDSL can be extended. The present invention describes a technique for extending the reach of VDSL without degrading the transmission capacity of shorter lines.

There are two different kind of cross-talk for wire communication, cross-talk in the Near- End (NEXT) and in the Far-End (FEXT). NEXT is the more damaging form of cross-talk, so it is desirable to design systems that suppress NEXT. With a smart duplex scheme it is possible to minimise NEXT between VDSL Systems. The duplex technique disclosed in our patent application PCT/SE 9600935 is intended to suppress NEXT. Using this technique it is possible to use any carrier for either the up-stream, or down-stream, transmission direction. This method is known as OFDD (Orthogonal Frequency Divided Duplex), also known as Zipper. The elements of OFDD are:

- different sub-carriers are used in the up-stream and down-stream transmission directions;
- time synchronisation is performed between all transmitters in the

ONUs and the NTs; and

- an extension of the cyclic prefix is added to compensate for delay propagation.

Related to NEXT, is near end echo produced in balanced hybrids. Our co-pending patent application Kgp 151/97 describes a hybrid circuit which substantially suppresses near end echo.

According to a first aspect of the present invention, there is provided a telecommunications system having a plurality of data modems linked to a central station by subscriber lines of differing lengths, in which duplex data is transmitted between said central station and one, or more, modems using VDSL, said subscriber lines being grouped into longer and shorter lines, characterised in that FDD is employed at lower frequencies for transmissions over said longer lines and OFDD is employed at higher frequencies for transmissions over said shorter lines.

Preferably, an extra cyclic prefix is used for OFDD transmissions over shorter lines, and frequencies above an FDD band are not used for longer lines.

Shorter lines may be classified as lines having a length less than X metres and longer lines may be classified as lines having a length equal to, or greater than X metres, where X is a design parameter selected for a given telecommunications system.

Said cyclic prefix may be dimensioned for a shorter line.

Preferably, said cyclic prefix is dimensioned for a line of length X metres.

Time-synchronisation may be performed between all transmitters in ONUs and NTs incorporated in said system.

Timing advance may be calculated for each line from the line's length.

Different sub-carriers may be used in up-stream and down-stream transmission directions.

A power boost may be applied to FDD band transmission.

Both ADSL and VDSL may be employed.

Both ADSL and VDSL may be employed on a single wire.

The frequency band employed for FDD may be the same as that employed for ASDL in both the up-stream and down-stream transmission directions.

Said FDD band frequencies may be power boosted to the same power level as that employed for ASDL.

According to a second aspect of the present invention, there is provided, in a telecommunications system having a plurality of data modems linked to a central station by subscriber lines of differing lengths, said subscriber lines being grouped into longer and shorter lines, a method of transmitting duplex data between said central station and one, or more, modems using VDSL, characterised by using FDD for transmission at lower frequencies over said longer lines and OFDD for transmission at higher frequencies over said shorter lines.

An extra cyclic prefix may be used for OFDD transmissions over shorter lines, and frequencies above an FDD band may not be used for transmission over longer lines.

Shorter lines may be classified as those lines having a length less than X metres and longer lines may be classified as those lines having a length equal to, or greater than X metres, where X is a design parameter selected for a given telecommunications system.

Said cyclic prefix may be dimensioned for a shorter line.

Said cyclic prefix may be dimensioned for a line of length X metres.

Time-synchronisation may be performed between all transmitters in ONUs and NTs incorporated in said system.

Timing advance may be calculated for each line from the line's length.

Different sub-carriers may be used in up-stream and down-stream transmission directions.

A power boost may be applied to FDD band transmissions.

Both ADSL and VDSL may be employed.

Both ADSL and VDSL may be employed on the same wire.

The same frequency band may be employed for FDD as that employed for ASDL in both the up-stream and down-stream transmission directions.

Said FDD band frequencies may be power boosted to the same power level as that employed for ASDL.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 illustrates, in schematic form, a VDSL transmission system having long and short lines.

In order to facilitate an understanding of the present invention a glossary of terms used in the description of the present invention is provided below:

ASDL: Asymmetric Digital Subscriber Line

FDD: Frequency Divided Duplex

FEXT: Far-End Cross Talk

NEXT: Near-End Cross talk

NT: Network Termination

OFDD: Orthogonal Frequency Divided Duplex

ONU: Optical Network Unit

VDSL: Very high rate Digital Subscriber Line

As previously explained, there are two different kind of cross-talk for wire communication, cross-talk in the Near- End (NEXT) and in the Far-End (FEXT). Because NEXT is the more damaging form of cross-talk, it is more important to suppress NEXT, than FEXT. With a smart duplex scheme it is possible to minimise NEXT between VDSL Systems. The duplex method described in our patent application PCT/SE 9600935 can be used to suppress NEXT. This technique includes the following elements:

- different sub-carriers are used in the up-stream and down-stream directions;

- time synchronisation is performed between all transmitters in the ONUs and the NTs; and

- an extension of the cyclic prefix is added to compensate for propagation delay.

The present invention combines the advantages of OFDD with Frequency Divided Duplex (FDD). FDD means that the up-stream and down-stream bands are divided into separate frequency bands that can be separated with filters. For FDD, NEXT is not a problem, provided that the separate frequency bands are filtered out properly. FDD has the disadvantage that it is a static duplex scheme

and it is not, therefore, possible to change the up-stream and down-stream bands without changing filters. The advantage of OFDD is that dynamic up-stream and down-stream allocation can be employed without increasing NEXT. On the other hand, OFDD has the disadvantage that an extended cyclic prefix must be used and this becomes large for longer lines, resulting in lost capacity.

The present invention uses FDD for lower frequencies, to extend the reach without an additional capacity loss. For higher frequencies an arbitrary up-stream/down-stream loading on the different OFDD carriers makes it possible to handle different symmetry/asymmetry rates for shorter wires. To fulfil the orthogonal requirements in OFDD, an extension of the cyclic prefix has to be added. This extra prefix has to be dimensioned from the propagation delay of the longest line. This means that the capacity loss caused by the cyclic prefix becomes larger for longer lines. When the new duplex technique of the present invention is used the extra cyclic prefix is dimensioned for a shorter line. There will be no extra capacity loss for longer lines and NEXT will not be increased. The present invention requires that:

- the extra cyclic prefix be dimensioned for X metres, where X is the length of a typical shorter line; and

- for lines longer than X metres the frequencies above the FDD band are not used, i.e. FDD is used for longer lines and OFDD is used for lines less than X metres in length.

This in turn means that:

- time-synchronisation is performed between all transmitters in the ONUs and the NTs;

- timing advance is calculated from the line length; and

- different sub-carriers are used in up-stream and down-stream directions.

To further extend the reach of a VDSL system, according to the present invention, a power boost is switched on for longer lines. The power boost increases the transmitted power over the FDD band.

In Figure 1 there is shown two different line lengths with 2 groups of VDSL modems. The distance between the ONU and group 2 is less than X metres and the distance to group 1 is larger than X metres. The precise value of X is a design choice. With the new method, group 1 modems only use FDD which eliminates NEXT between group 1 modems. Group two modems can use higher frequencies, as well as lower frequencies, if the extra cyclic prefix is dimensioned for X metres. If all requirements for OFDD are fulfilled, there will be no NEXT between group 2 modems. If timing advance is calculated for each wire, then the symbols transmitted from the group 1 modems will be inside the extra cyclic prefix for the part of the wire where the two groups affect each other and the requirements for OFDD are fulfilled.

An interesting aspect of the duplex technique employed in the present invention is that co-existence problems with ADSL can be solved. The problem with mixing ADSL and VDSL on the same wire is the large NEXT from ADSL into VDSL. With the present invention it is possible to solve this problem without any NEXT between ADSL and VDSL. If we let:

- the up-stream and down-stream bands, in the FDD band, be the same as the band used in ASDL; and

- the power boost used for these bands be the same as the power levels used in ADSL,

then VDSL can offer ADSL capacity for longer lines and still offer VDSL capacity for short lines without any extra loss of capacity.

The present invention has the following advantages, it can:

- increase the capacity and the reach of VDSL systems;

- be implemented to solve the co-existence problem between ADSL and VDSL; and

- reduce the capacity loss for OFDD on long lines.

The choice of a value for X, is a design decision made for a given system. Those skilled in the art will appreciate the factors to be taken into account in selecting the value for X.

The terms "shorter" and "longer", as herein used with reference to subscriber lines, are intended to indicate the relative length of subscriber lines relative to each other, i.e. subscriber lines can be classified into two groups, depending on their length relative to each other. The question of whether a particular line is to be regarded as longer, rather than shorter is, as indicated above, a design decision. In the same way, the terms "higher" and "lower", as herein used with reference to frequency, is intended to indicate the relative values, with respect to each other, of the frequency bands employed for OFDD and FDD transmissions, i.e. the frequency band used for OFDD will be of higher frequency than the frequency band used for FDD.

For the avoidance of doubt, the term OFDD, as used in this specification, is intended to embrace similar duplex techniques, such as those employing DMT, wavelet multiplexing, or the like.

CLAIMS

1. A telecommunications system having a plurality of data modems linked to a central station by subscriber lines of differing lengths, in which duplex data is transmitted between said central station and one, or more, modems using VDSL, said subscriber lines being grouped into longer and shorter lines, characterised in that FDD is employed at lower frequencies for transmissions over said longer lines and OFDD is employed at higher frequencies for transmissions over said shorter lines.

2. A telecommunications system, as claimed in claim 2, characterised in that an extra cyclic prefix is used for OFDD transmissions over shorter lines, and in that frequencies above an FDD band are not used for longer lines.

3. A telecommunications system, as claimed in either claim 1, or claim 2, characterised in that shorter lines are classified as lines having a length less than X metres and longer lines are classified as lines having a length equal to, or greater than X metres, where X is a design parameter selected for a given telecommunications system.

4. A telecommunications system, as claimed in either claim 2, or claim 3, characterised in that said cyclic prefix is dimensioned for a shorter line.

5. A telecommunications system, as claimed in claim 3, or claim 4, when dependent on claim 2, characterised in that said cyclic prefix is dimensioned for a line of length X metres.

6. A telecommunications system, as claimed in any of claims 2 to 5, characterised in that time-synchronisation is performed between all transmitters in ONUs and NTs incorporated in said system.

7. A telecommunications system, as claimed in any of claims 2 to 6, characterised in that timing advance is calculated for each line from the line's

length.

8. A telecommunications system, as claimed in any previous claim, characterised in that different sub-carriers are used in up-stream and down-stream transmission directions.

9. A telecommunications system, as claimed in any previous claim, characterised in that a power boost is applied to FDD band transmission.

10. A telecommunications system, as claimed in any previous claim, characterised in that both ADSL and VDSL are employed.

11. A telecommunications system, as claimed in any previous claim, characterised in that both ADSL and VDSL are employed on a single wire.

12. A telecommunications system, as claimed in either claim 10, or claim 11, characterised in that the frequency band employed for FDD is the same as that employed for ASDL in both the up-stream and down-stream transmission directions.

13. A telecommunications system, as claimed in any of claims 10 to 12, characterised in that said FDD band frequencies are power boosted to the same power level as that employed for ASDL.

14. In a telecommunications system having a plurality of data modems linked to a central station by subscriber lines of differing lengths, said subscriber lines being grouped into longer and shorter lines, a method of transmitting duplex data between said central station and one, or more, modems using VDSL, characterised by using FDD for transmission at lower frequencies over said longer lines and OFDD for transmission at higher frequencies over said shorter lines.

15. A method, as claimed in claim 14, characterised by using an extra cyclic prefix for OFDD transmissions over shorter lines, and by not using frequencies above an FDD band for transmission over longer lines.

16. A method, as claimed in either claim 14, or claim 15, characterised by classifying shorter lines as those lines having a length less than X metres and longer lines as those lines having a length equal to, or greater than, X metres, where X is a design parameter selected for a given telecommunications system.

17. A method, as claimed in either claim 15, or claim 16, characterised by dimensioning said cyclic prefix for a shorter line.

18. A method, as claimed in claim 16, or claim 17 when dependent on claim 15, characterised by dimensioning said cyclic prefix for a line of length X metres.

19. A method, as claimed in any of claims 15 to 18, characterised by performing time-synchronisation between all transmitters in ONUs and NTs incorporated in said system.

20. A method, as claimed in any of claims 15 to 19, characterised by calculating timing advance for each line from the line's length.

21. A method, as claimed in any of claims 14 to 20, characterised by using different sub-carriers in up-stream and down-stream transmission directions.

22. A method, as claimed in any of claims 14 to 21, characterised by applying a power boost to FDD band transmissions.

23. A method, as claimed in any of claims 14 to 22, characterised by employing both ADSL and VDSL.

24. A method, as claimed in any of claims 14 to 22, characterised by employing both ADSL and VDSL on the same wire.

25. A method, as claimed in either claim 23, or claim 24, characterised by employing the same frequency band for FDD as that employed for ASDL in both the up-stream and down-stream transmission directions.

26. A method, as claimed in any of claims 23 to 25, characterised by power boosting said FDD band frequencies to the same power level as that employed for ASDL.

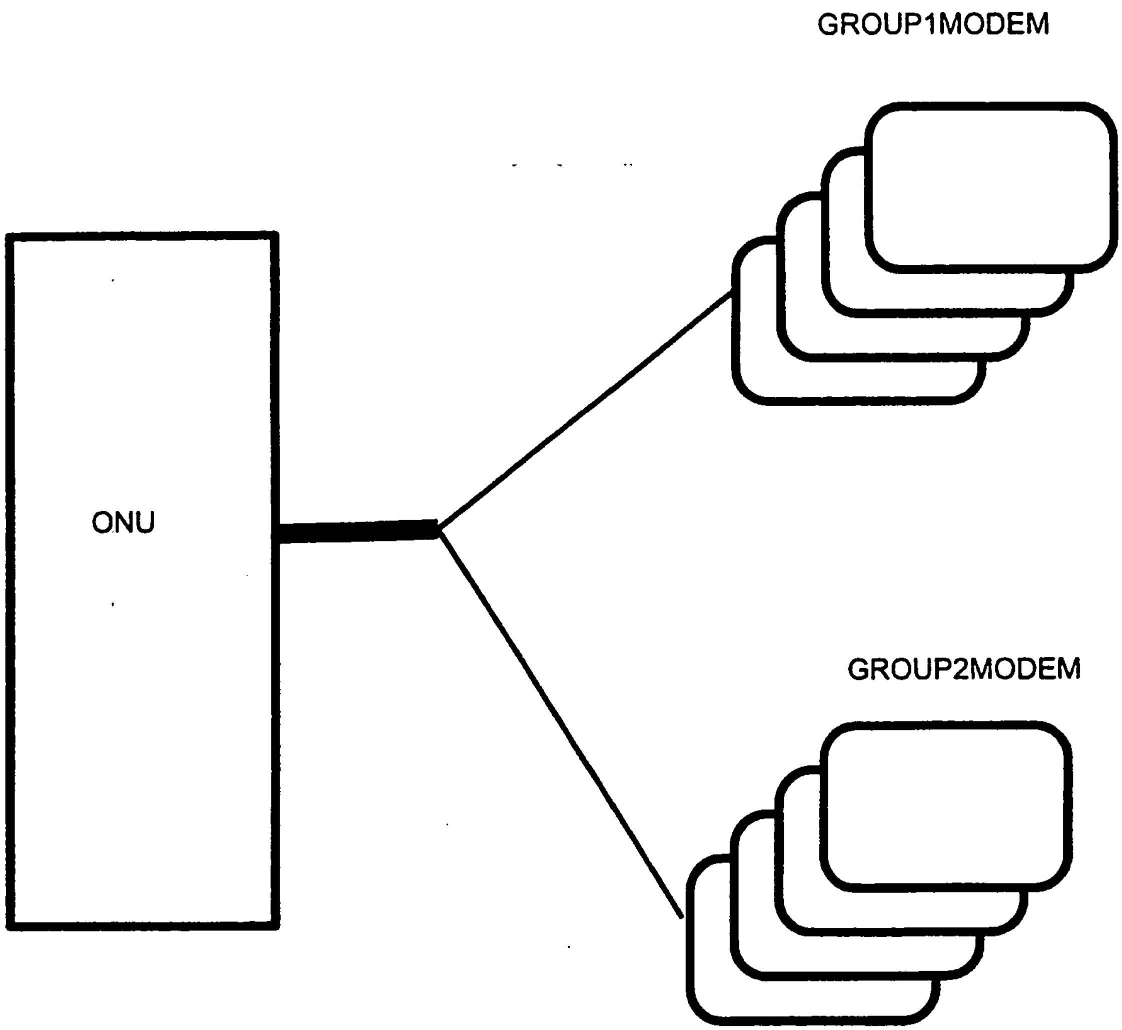

FIGURE1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01973

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04B 3/50, H04L 5/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04B, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9706619 A1 (TELIA AB), 20 February 1997 (20.02.97), cited in the application	1-26
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9706619 A1	20/02/97	EP 0883944 A	16/12/98
		SE 9502775 A	05/02/97

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